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INTERNET MESSAGE PROTOCOL

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PREFACE

This is the second edition of this specification and should be treated as a request for comments, advice, and suggestions. A great deal of prior work has been done on computer aided message systems and some of this is listed in the reference section. This specification was shaped by many discussions with members of the ARPA research community, and others interested in the development of computer aided message systems. This document was prepared as part of the ARPA sponsored Internetwork Concepts Research Project at ISI, with the assistance of Greg Finn, Suzanne Sluizer, Alan Katz, Paul Mockapetris, and Linda Sato.

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1. INTRODUCTION

This document describes an internetwork message system. The system is designed to transmit messages between message processing modules according to formats and procedures specified in this document. The message processing modules are processes in host computers. Message processing modules are located in different networks and together constitute an internetwork message delivery system.

This document is intended to provide all the information necessary to implement a compatible cooperating module of this internetwork message delivery system.

1.1. Motivation

As computer supported message processing activities grow on individual host computers and in networks of computers, there is a natural desire to provide for the interconnection and interworking of such systems. This specification describes the formats and procedures of a general purpose internetwork message system, which can be used as a standard for the interconnection of individual message systems, or as a message delivery system in its own right.

This system also provides for the communication of data items beyond the scope of contemporary message systems. Messages can include data objects which could represent drawings, or facsimile images, or digitized speech. One can imagine message stations equipped with speakers and microphones (or telephone hand sets) where the body of a message or a portion of it is recorded digitized speech. The output terminal could include a graphics display, and the message might present a drawing on the display, and verbally (via the speaker) describe certain features of the drawing. This specification provides for the composition of complex data objects and their encoding in machine independent basic data elements.

1.2. Scope

The Internet Message Protocol is intended to be used for the transmission of messages between networks. It may also be used for the local message system of a network or host. This specification was

developed in the context of the ARPA work on the interconnection of networks, but it is thought that it has a more general scope.

The focus here is on the internal mechanisms to transmit messages, rather than the external interface to users. It is assumed that a number of user interface programs will exist. These will be both new programs designed to work with this system and old programs designed to work with earlier systems.

1.3. The Internetwork Environment

The internetwork message environment consists of processes which run in hosts which are connected to networks which are interconnected by gateways. Each network consists of many different hosts. The networks are tied together through gateways. The gateways are essentially hosts on two (or more) networks and are not assumed to have much storage capacity or to "know" which hosts are on the networks to which they are attached [1,2].

1.4. Model of Operation

This protocol is implemented in a process called a Message Processing Module or MPM. The MPMs exchange messages by establishing full duplex communication and sending the messages in a fixed format described in this document. The MPM may also communicate other information by means of commands described here.

A message is formed by a user interacting with a User Interface Program or UIP. The user may utilize several commands to create various fields of the message and may invoke an editor program to correct or format some or all of the message. Once the user is satisfied with the message it is submitted for transmission by placing it in a data structure read by the MPM.

The MPM discovers the unprocessed input data (either by a specific request or by a general background search), examines it, and, using routing tables (or some other method), determines which outgoing link to use. The destination may be another user on the same host, one on another host on a network in common with the same host, or a user in another network.

In the first case, another user on this host, the MPM places the message in a data structure read by the destination user, where that user's UIP will look for incoming messages.

In the second case, the user on another host in this network, the MPM transmits the message to the MPM on that host. That MPM then repeats

the routing decision, and discovering the destination is local to it, places the message in the data structure shared with the destination user.

In the third case, the user on a host in another network, the MPM transmits the messages to an MPM in that network if it knows how to establish a connection directly to it; otherwise, the MPM transmits the message to an MPM that is "closer" to the destination. An MPM might not know of direct connections to MPMs in all other networks, but it must be able to select a next MPM to handle the message for each possible destination network.

An MPM might know a way to establish direct connections to each of a few MPMs in other nearby networks, and send all other messages to a particular big brother MPM that has a wider knowledge of the internet environment.

An individual network's message system may be quite different from the internet message system. In this case, intranet messages will be delivered using the network's own message system. If a message is addressed outside the network, it is given to an MPM which then sends it through the appropriate gateways to (or towards) the MPM in the destination network. Eventually, the message gets to an MPM on the network of the recipient of the message. The message is then sent via the local message system to that host.

When local message protocols are used, special conversion programs are required to transform local messages to internet format when they are going out, and to transform internet messages to local format when they come into the local environment. Such transformations potentially lead to information loss. The internet message format attempts to provide features to capture all the information any local message system might use. However, a particular local message system is unlikely to have features equivalent to all the possible features of the internet message system. Thus, in some cases the transformation of an internet message to a local message discards some of the information. For example, if an internet message carrying mixed text and speech data in the body is to be delivered in a local system which only carries text, the speech data may be replaced by the text string "There was some speech here". Such discarding of information is to be avoided when at all possible, and to be deferred as long as possible; still, the possibility remains that in some cases it is the only reasonable thing to do.

1.5. Interfaces

The MPM calls on a reliable communication procedure to communicate with other MPMs. This is a Transport Level protocol such as the Transmission Control Protocol (TCP) [3]. The interface to such a procedure conventionally provides calls to open and close connections, send and receive data on a connection, and some means to signal and be notified of special conditions (i.e., interrupts).

The MPM receives input and produces output through data structures that are produced and consumed respectively by user interface (or other) programs.

2. FUNCTIONAL DESCRIPTION

This section gives an overview of the Internet Message System and its environment.

2.1. Terminology

The messages are routed by a process called the Message Processing Module or MPM. Messages are created and consumed by User Interface Programs (UIPs) in conjunction with users.

The basic unit transferred between MPMs is called a message. A message is made up of a transaction identifier (which uniquely identifies the message), a command (which contains the necessary information for delivery), and document. The document may have a header and a body.

For a personal letter the document body corresponds to the contents of the letter; the document header corresponds to the date line, greeting, and signature.

For an inter-office memo the document body corresponds to the text; the document header corresponds to the header of the memo.

The commands correspond to the information used by the Post Office or the mail room to route the letter or memo. Some of the information in the command is supplied by the UIP.

2.2. Assumptions

The following assumptions are made about the internetwork environment:

In general, it is not known what format intranet addresses will assume. Since no standard addressing scheme would suit all networks, it is safe to assume there will be several and that they will change with time. Thus, frequent software modification throughout all internet MPMs would be required if such MPMs were to know about the formats on many networks. Therefore, each MPM which handles internet messages is required to know only the minimum necessary to deliver them.

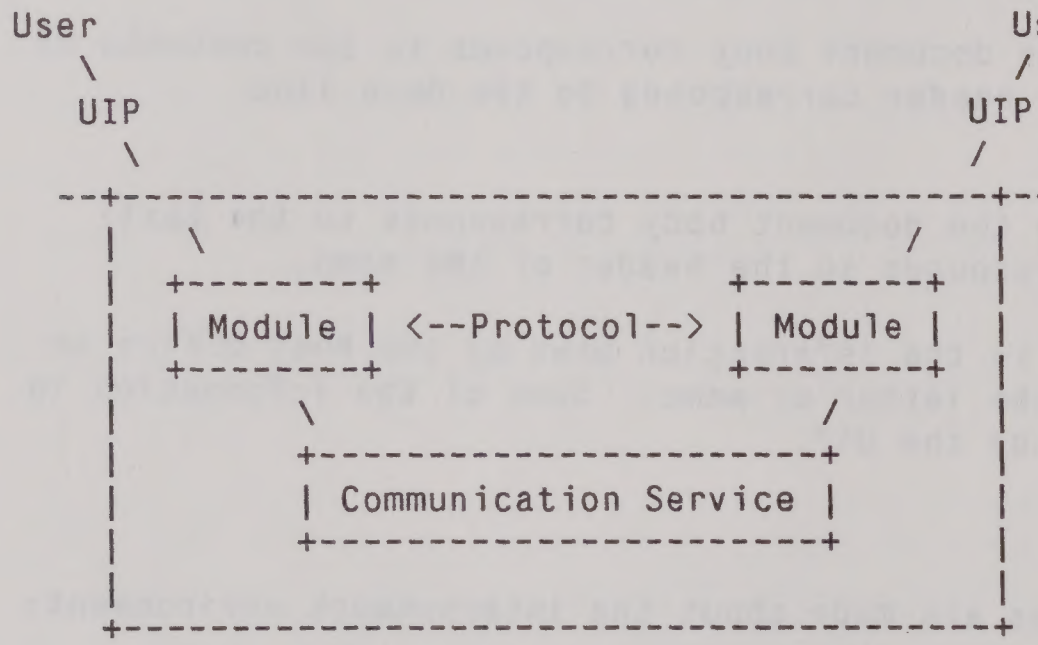
Each MPM is required to know completely only the addressing format of its own network(s). In addition, the MPM must be able to select an output link for each message addressed to another network or host. This does not preclude more intelligent behavior on the part of a given MPM, but at least this minimum is necessary. Each network has a unique name and numeric address. Such names and addresses are

registered with a naming authority and may be listed in documents such as Assigned Numbers [4].

Each MPM will have a unique internet address. This feature will enable every MPM to place a unique "handling-stamp" on a message which passes through the MPM enroute to delivery.

2.3. General Specification

There are several aspects to a distributed service to be specified. First, there is the service to be provided; that is, the characteristics of the service as seen by its users. Second, there is the service it uses; that is, the characteristics it assumes to be provided by some lower level service. And third, there is the protocol used between the modules of the distributed service.



Message Service

Figure 1.

The User/Message Service Interface

The service the message delivery system provides is to accept messages conforming to a specified format, to attempt to deliver those messages, and to report on the success or failure of the delivery attempt. This service is provided in the context of an interconnected system of networks and may involve relaying a message through several intermediate MPMs via different communication services.

The Message/Communication Service Interface

The message delivery system calls on a communication service to transfer information from one MPM to another. There may be different communication services used between different pairs of MPMs, though all communication services must meet the service characteristics described below.

It is assumed that the communication service provides a reliable two-way data stream. Such a data stream can usually be obtained in computer networks from the transport level protocol, for example, the Transmission Control Protocol (TCP) [3]. In any case, the properties the communication service must provide are:

- o Logical connections for two way simultaneous data flow of arbitrary data (i.e., no forbidden codes). All data sent is delivered in order.

- o Simple commands to open and close the connections, and to send and receive data on the connections.

- o Controlled flow of data so that data is not transmitted faster that the receiver chooses to consume it (on the average).

- o Transmission errors are corrected without user notification or involvement of the sender or receiver. Complete breakdown on communication is reported to the sender or receiver.

The Message-Message Protocol

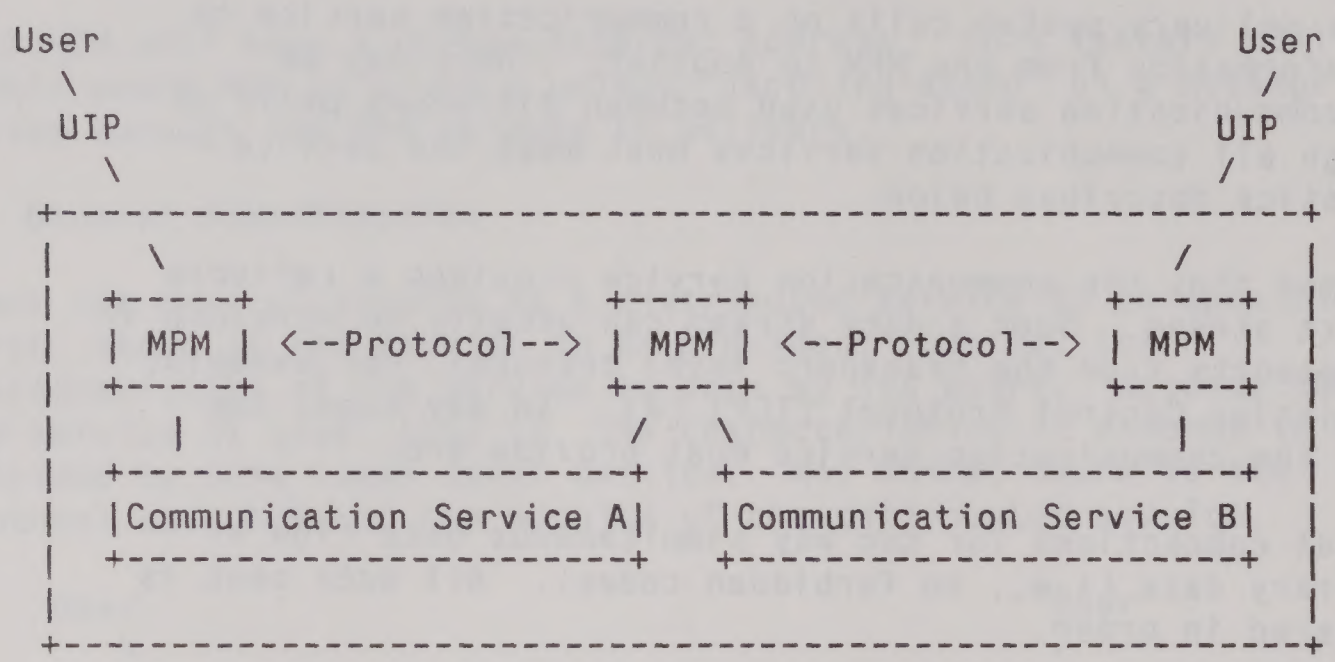
The protocol used between the distributed modules of the message delivery system, that is, the MPMs, is a small set of commands which convey requests and replies. These commands are encoded in a highly structured and rigidly specified format.

2.4. Mechanisms

MPMs are processes which use some communication service. A pair of MPMs which can communicate reside in a common interprocess communication environment. An MPM might exist in two (or more) interprocess communication environments, and such an MPM might act to relay messages between MPMs. Messages may be held for a time in an MPM; the total path required for delivery need not be available simultaneously.

From the time a message is accepted from a UIP by an MPM until it is delivered to a UIP by an MPM and an acknowledgment is returned to the

originating UIP, the message is considered to be active in the message system.

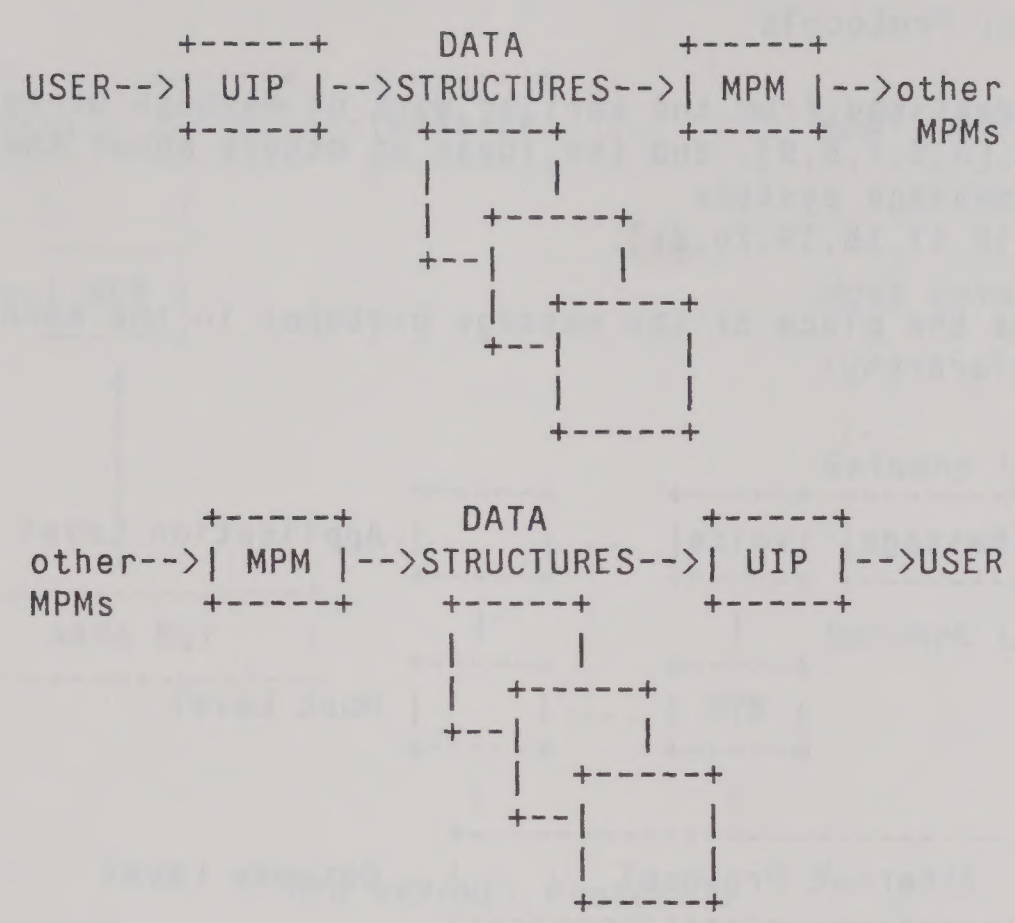


Message Service with Internal Relaying

Figure 2.

It should be clear that there are two roles an MPM can play, an end-point MPM or a relay MPM. Most MPMs will play both roles. A relay MPM acts to relay messages from one communication environment to another. An end-point MPM acts as a source or destination of messages.

The transfer of data between UIPs and MPMs is viewed as the exchange of data structures which encode messages. The transfer of data between MPMs is also in terms of the transmission of structured data.



Message Flow

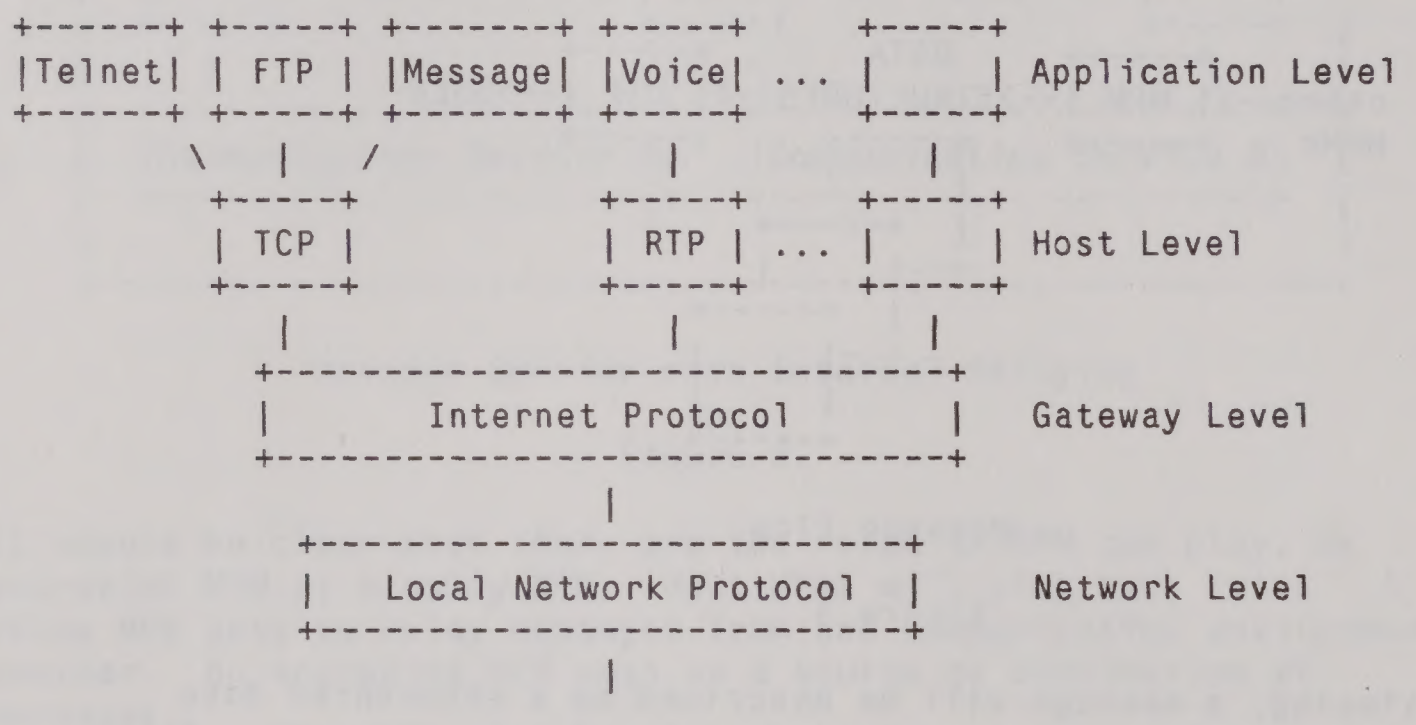
Figure 3.

In the following, a message will be described as a structured data object represented in a particular kind of typed data elements. This is how a message is presented when transmitted between MPMs or exchanged between an MPM and a UIP. Internal to an MPM (or a UIP), a message may be represented in any convenient form.

2.5. Relation to Other Protocols

This protocol the benefited from the earlier work on message protocols in the ARPA Network [5,6,7,8,9], and the ideas of others about the design of computer message systems [10,11,12,13,14,15,16,17,18,19,20,21].

Figure 4 illustrates the place of the message protocol in the ARPA internet protocol hierarchy:



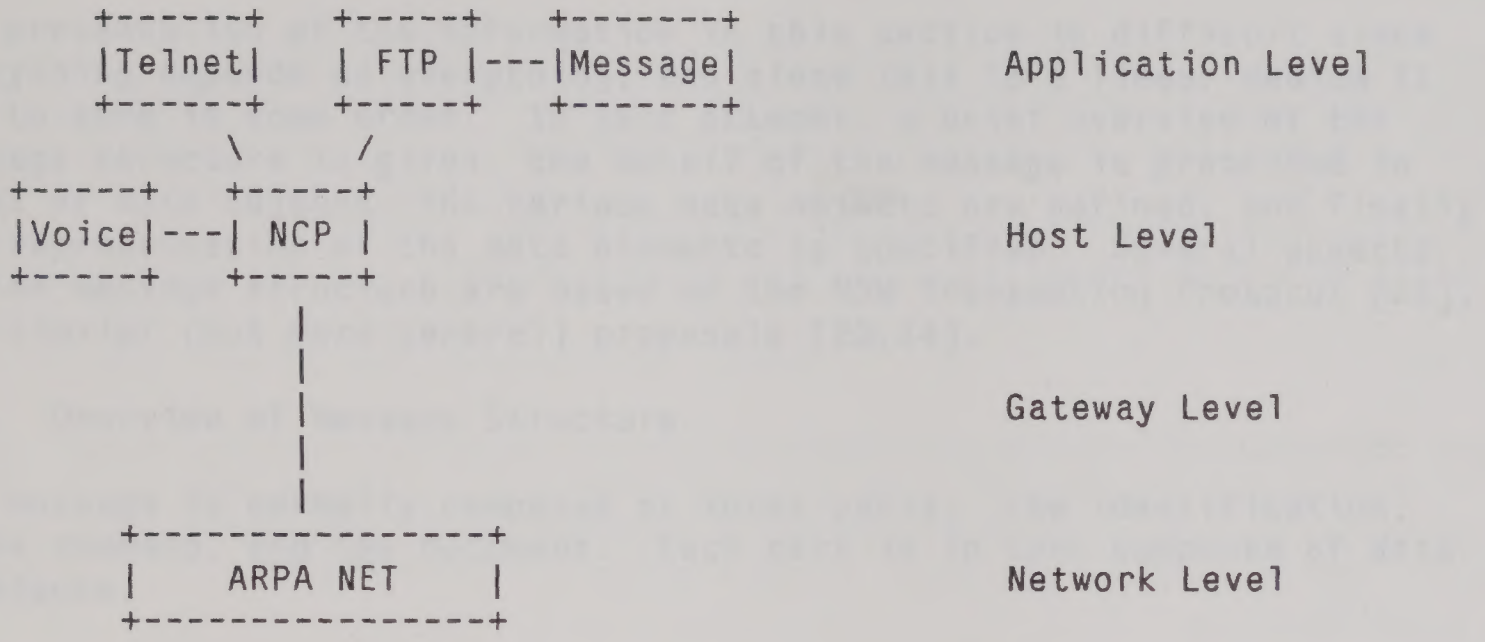
Protocol Relationships

Figure 4.

Note that "local network" means an individual or specific network. For example, the ARPANET is a local network.

The message protocol interfaces on one side to user interface programs and on the other side to a reliable transport protocol such as TCP.

In this internet message system the MPMs communicate directly using the lower level transport protocol. In the old ARPANET system, message transmission was part of the file transfer protocol.



Old ARPANET Protocols

Figure 5.

Note that in the old ARPANET protocols one can't send messages (or communicate in any way) to other networks since it has no gateway level or internet protocol [5].

3. DETAILED SPECIFICATION

The presentation of the information in this section is difficult since everything depends on everything, and since this is a linear medium it has to come in some order. In this attempt, a brief overview of the message structure is given, the detail of the message is presented in terms of data objects, the various data objects are defined, and finally the representation of the data elements is specified. Several aspects of the message structure are based on the NSW Transaction Protocol [22], and similar (but more general) proposals [23,24].

3.1. Overview of Message Structure

A message is normally composed of three parts: the identification, the command, and the document. Each part is in turn composed of data objects.

The identification part is composed of a transaction number assigned by the originating MPM and the MPM identifier.

The command part is composed of an operation type, an operation code, the arguments to the operation, error information, the destination mailbox, and a trace. The trace is a list of the MPMs that have handled this message.

The document part is a data structure. The message delivery system does not depend on the contents of the document part. A standard for the document part is defined in reference [25].

The following sections define the representation of a message as a structured object composed of other objects. Objects in turn are represented using a set of basic data elements.

The basic data elements are defined in section 3.7. In summary, these are exact forms for representing integers, strings, booleans, et cetera. There are also two elements for building data structures: list and property list. Lists are simple lists of elements, including lists. Property lists are lists of pairs of elements, where the first element of each pair names the pair. That is, a property list is a list of <name,value> pairs. In general, when an object is composed of multiple instances of a simpler object it is represented as a list of the simpler objects. When an object is composed of a variety of simpler objects it is represented as a property list of the simpler objects. In most uses of the property list representation, the presence of <name,value> pairs in addition to those specifically required is permitted.

3.2. Message Structure

An internet message is composed of two or three parts. The first is the Identification which identifies the transaction; the second is the Command; and the optional third part is the Document.

When shipped between two MPMs, a message will take the form of a property list, with the <name,value> pairs in this order.

MESSAGE is:

(Identification, Command [, Document])

It is convenient to batch several messages together, shipping them as a unit from one MPM to another. Such a group of messages is called a message-bag.

A message-bag will be a list of Messages; each Message is of the form described above.

MESSAGE-BAG is:

(Message, Message, ...)

The Identification

This is the transaction identifier. It is assigned by the originating MPM. The identification is composed of the MPM identifier, and a transaction number unique in that context for this message.

The Command

The command is composed of a mailbox, an operation code, the arguments to that operation, some error information, and a trace of the route of this message. The command is implemented by a property list which contains <name,value> pairs, where the names are used to identify the associated argument values.

The Document

The document portion of an internet message is optional and when present is a data structure as defined in [25].

3.3. Identification

Each message must have a unique identifier while it exists in the message delivery system. This is provided by the combination of the unique identifier of the MPM and a unique transaction number chosen for the message by this MPM.

IDENTIFICATION is:

(mpm-identifier, transaction-number)

The mpm-identifier is based on the host address of the computer in which the MPM resides. If there is more than one MPM in a host the mpm-identifier must be extended to distinguish between the co-resident MPMs.

3.4. Command

This section describes the commands MPMs use to communicate between themselves. The commands come in pairs, with each request having a corresponding reply.

COMMAND is:

(mailbox, operation, [arguments,]
[error-class, error-string,] trace)

The mailbox is the "To" specification of the message. Mailbox is a property list of general information, some of which is the essential information for delivery, and some of which could be extra information which may be helpful for delivery. Mailbox is different from address in that address is a very specific property list without extra information. The mailbox includes a specification of the user, when a command is addressed to the MPM itself (rather than a user it serves) the special user name "*MPM*" is specified.

The operation is the name of the operation or procedure to be performed.

The arguments to the operation vary from operation to operation.

The error information is composed of a error class code and a character string, and indicates what, if any, error occurred. The error information is normally present only in replies, and not present in requests.

The trace is a list of the MPMs that have handled the message. Each MPM must add its handling-stamp to the list.

3.4.1. Command: DELIVER

function: Sends a document to a mailbox.

reply: The reply is ACKNOWLEDGE.

arguments:

type-of-service: one or more of the following:

"REGULAR" regular delivery
"FORWARD" message forwarding
"GENDEL" general delivery
"PRIORITY" priority delivery

3.4.2. Command: ACKNOWLEDGE

function: Reply to DELIVER.

arguments:

reference: the identifier of the originating message.

address:

The address is the final mailbox the message was delivered to. This would be different from the original mailbox if the message was forwarded, and is limited to the essential information needed for delivery.

type-of-service: one of the following:

"GENDEL" message was accepted for general delivery
"REGULAR" message was accepted for normal delivery
"PRIORITY" message was accepted for priority delivery

error-class:
error-string:

If the document was delivered successfully, the error information has class 0 and string "ok". Otherwise, the error information has a non-zero class and the string would be one of "no such user", "no such host", "no such network", "address ambiguous", or a similar response.

trail: the trace from the DELIVER command.

3.4.3. Command: PROBE

function: Finds out if specified mailbox (specified in mailbox of the command) exists at a host.

reply: The reply is RESPONSE.

arguments: none.

3.4.4. Command: RESPONSE

function: Reply to PROBE.

arguments:

reference: the identification of the originating PROBE.

address: a specific address.

error-class:
error-string:
If the mailbox was found the error class is 0 and the error string is "OK". If the mailbox has moved and a forwarding address in known the error class is 1 and the error string is "Mailbox moved, see address". Otherwise the error class is greater than 1 and the error string may be one of the following: "Mailbox doesn't exist", "Mailbox full", "Mailbox has moved, try the new location indicated in the address".

trail: the trace which came from the originating PROBE.

3.4.5. Command: CANCEL

function: Abort request for specified transaction.

reply: The reply is CANCELED.

arguments:

reference: identification of transaction to be canceled.

3.4.6. Command: CANCELED

function: Reply to CANCEL.

arguments:

reference: identification of canceled transaction.

error-class:
error-string:

If the command was canceled the error class is 0 and the error string is "OK". Otherwise the error class is positive and the error string may be one of the following: "No such transaction", or any error for an unreachable mailbox.

trail: the trace of the CANCEL command.

To summarize again, a command generally consists of a property list of the following objects:

name	value
mailbox	property list of address information
operation	name of operation
arguments	---
error-class	numeric class of the error
error-string	text description of the error
trace	list (handling-stamp, ...)

3.5. Document

The actual document follows the command. The message delivery system does not depend on the document, examine it, or use it in any way. The standard for the contents of the document is reference [25]. The document must be the last <name,value> pair in the message property list.

3.6. Message Objects

In the composition of messages, we use a set of objects such as mailbox or date. These objects are encoded in basic data elements. Some objects are simple things like integers or character strings, other objects are more complex things built up of lists or property lists.

The following is a list of the objects used in messages. The object descriptions are in alphabetical order.

Action

The type of handling action taken by the MPM when processing a message. One of ORIGIN, RELAY, FORWARD, or DESTINATION.

Address

Address is intended to contain the minimum information necessary to deliver a message, and no more (compare with mailbox).

An address is a property list. An address contains the following <name,value> pairs:

name	description
NET	network name
HOST	host name
USER	user name

or:

name	description
MPM	mpm-identifier
USER	user name

Answer

A yes (true) or no (false) answer to a question.

Arguments

Many operations require arguments, which differ from command to command. This "object" is a place holder for the actual arguments when commands are described in a general way.

City

The character string name of a city.

Command

(mailbox, operation [,arguments]
[,error-class, error-string], trace)

Country

The character string name of a country.

Date

The date and time are represented according to the International Standards Organization (ISO) recommendations [26,27,28]. Taken together the ISO recommendations 2014, 3307, and 4031 result in the following representation of the date and time:

yyyy-mm-dd-hh:mm:ss,fff+hh:mm

Where yyyy is the four-digit year, mm is the two-digit month, dd is the two-digit day, hh is the two-digit hour in 24 hour time, mm is the two-digit minute, ss is the two-digit second, and fff is the decimal fraction of the second. To this basic date and time is appended the offset from Greenwich as plus or minus hh hours and mm minutes.

The time is local time and the offset is the difference between local time and Coordinated Universal Time (UTC). To convert from local time to UTC algebraically subtract the offset from the local time.

For example, when the time in
Los Angeles is 14:25:00-08:00
the UTC is 22:25:00

or when the time in
Paris is 11:43:00+01:00
the UTC is 10:43:00

Document

The document is the user's composition and is not used by the message delivery system in any way.

Error-Class

A numeric code for the class of the error. The error classes are coded as follows:

= 0: indicates success, no error.
This is the normal case.
= 1: failure, address changed.
This error is used when forwarding is possible, but not allowed by the type of service specified.
= 2: failure, resources unavailable.
These errors are temporary and the command they respond to may work if attempted at a later time.
= 3: failure, user error.
For example, unknown operation, or bad arguments.
= 4: failure, MPM error. Recoverable.
These errors are temporary and the command they respond to may work if attempted at a later time.
= 5: failure, MPM error. Permanent.
These errors are permanent, there is no point in trying the same command again.
= 6: Aborted as requested by user.
The response to a successfully canceled command.

Error-String

This is a character string describing the error. Possible errors:

error-string	error-class
No errors	0
Ok	0
Mailbox Moved, see address	1
Mailbox Full, try again later	2
Syntax error, operation unrecognized	3
Syntax error, in arguments	3
No Such User	3
No Such Host	3
No Such Network	3
No Such Transaction	3
Mailbox Does Not Exist	3
Ambiguous Address	3
Server error, try again later	4
No service available	5
Command not implemented	5
Aborted as requested by user	6

Handling-Stamp

The handling-stamp indicates the MPM, the date (including the time) that a message was processed by an MPM, and the type of handling action taken.

(mpm-identifier, date, action)

Host

The character string name of a host.

Identification

This is the transaction identifier associated with a particular message. It is the transaction number, and the MPM identifier of the originating MPM.

(mpm-identifier, transaction-number)

Internet Address

This identifies a host in the ARPA internetwork environment. When used as a part of identification, it identifies the originating host of a message. The internet address is a 32 bit number, the higher order 8 bits identify the network, and the lower order 24 bits identify the host on that network [2]. For use in the MPMs the internet address is divided into eight bit fields and the value of each field is represented in decimal digits. For example, the ARPANET address of ISIE is 167837748 and is represented as 10,1,0,52. Further, this representation may be extended to include an address within a host, such as the TCP port of the MPM, for example, 10,1,0,52,0,45.

Mailbox

This is the destination address of a user of the internetwork mail system. Mailbox contains information such as network, host, location, and local user indentifier of the recipient of the message. Some information contained in mailbox may not be necessary for delivery.

As an example, when one sends a message to someone for the first time, he may include many items which are not necessary simply to insure delivery. However, once he gets a reply to this message, the reply will contain an Address (as opposed to Mailbox) which may be used from then on.

A mailbox is a property list. A mailbox might contain the following <name,value> pairs:

name	description
MPM	mpm-identifier
NET	network name
HOST	host name
PORT	address of MPM within the host
USER	user name
ORG	organization name
CITY	city
STATE	state
COUNTRY	country
ZIP	zip code
PHONE	phone number

The minimum mail box is an Address.

MPM-Identifier

The internetwork address of the MPM. This may be the ARPA Internet Address or an X.121 Public Data Network Address [29]. The mpm-identifier is a property list which has one <name,value> pair. This unusual structure is used so that it will be easy to determine the type of address used.

Network

This character string name of a network.

Operation

This names the operation or procedure to be performed. It is a character string name.

Organization

This character string name of a organization.

Phone

This character string name representation of a phone number. For example the phone number of ISI is 1 (international region) + 213 (area code) + 822 (central office) + 1511 (station number) = 12138221511.

Port

This names the port or subaddress within a host of the MPM. The default port for the MPM is 45 (55 octal) [4].

Reference

The reference is an identification from an earlier message.

State

The character string name of a state.

Trace

Each MPM that handles the message must add its handling-stamp to this list. This will allow detection of messages being sent in a loop within the internet mail system, and aid in fault isolation.

Trail

When a message is sent through the internetwork environment, it acquires this trace, a list of MPMs that have handled the message. This list is then carried as the trail in a reply or acknowledgment of that message. Requests and replies always have a trace and each MPM adds its handling-stamp to this trace. Replies, in addition, have a trail which is the complete trace of the original message.

Transaction Number

This is a number which is uniquely associated with this transaction by the originating MPM. It identifies the transaction. (A transaction is a message and acknowledgment.) A transaction number must be unique during the time which the message (a request or reply) containing it could be active in the network.

Type-of-Service

A service parameter for the delivery of a message, for instance a message could be delivered (REGULAR), forwarded (FORWARD), turned over to general delivery (GENDEL) (i.e., allow a person to decide how to further attempt to deliver the message), or require priority handling (PRIORITY).

User

The character string name of a user.

X121 Address

This identifies a host in the Public Data Network environment. When used as a part of identifier, it identifies the originating host of a message. The X121 address is a sequence of up to 14 digits [29]. For use in the MPMs the X121 address is represented in decimal digits.

Zip Code

The character string representation of a postal zip code. The zip code of ISI is 90291.

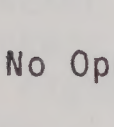
3.7. Data Elements

The data elements defined here are similar to the data structure and encoding used in NSW [30].

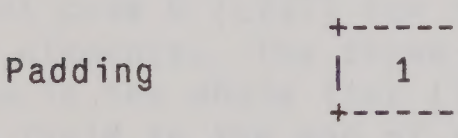
Each of the diagrams which follow represent a sequence of octets. Field boundaries are denoted by the "|" character, octet boundaries by the "+" character. Each element begins with a one-octet code. The order of the information in each element is left-to-right. In fields with numeric values the high-order (or most significant) bit is the left-most bit. For transmission purposes, the leftmost octet is transmitted first. Cohen has described some of the difficulties in mapping memory order to transmission order [31].

Code Type Representation

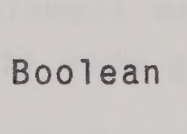
0 No Operation



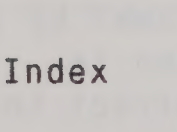
1 Padding



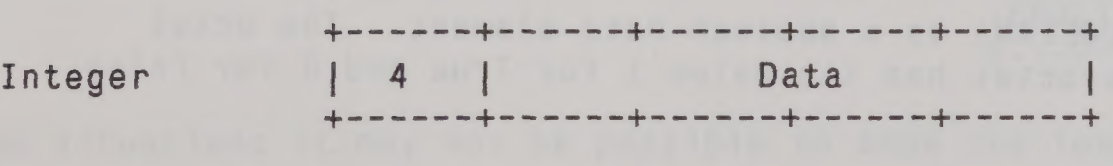
2 Boolean

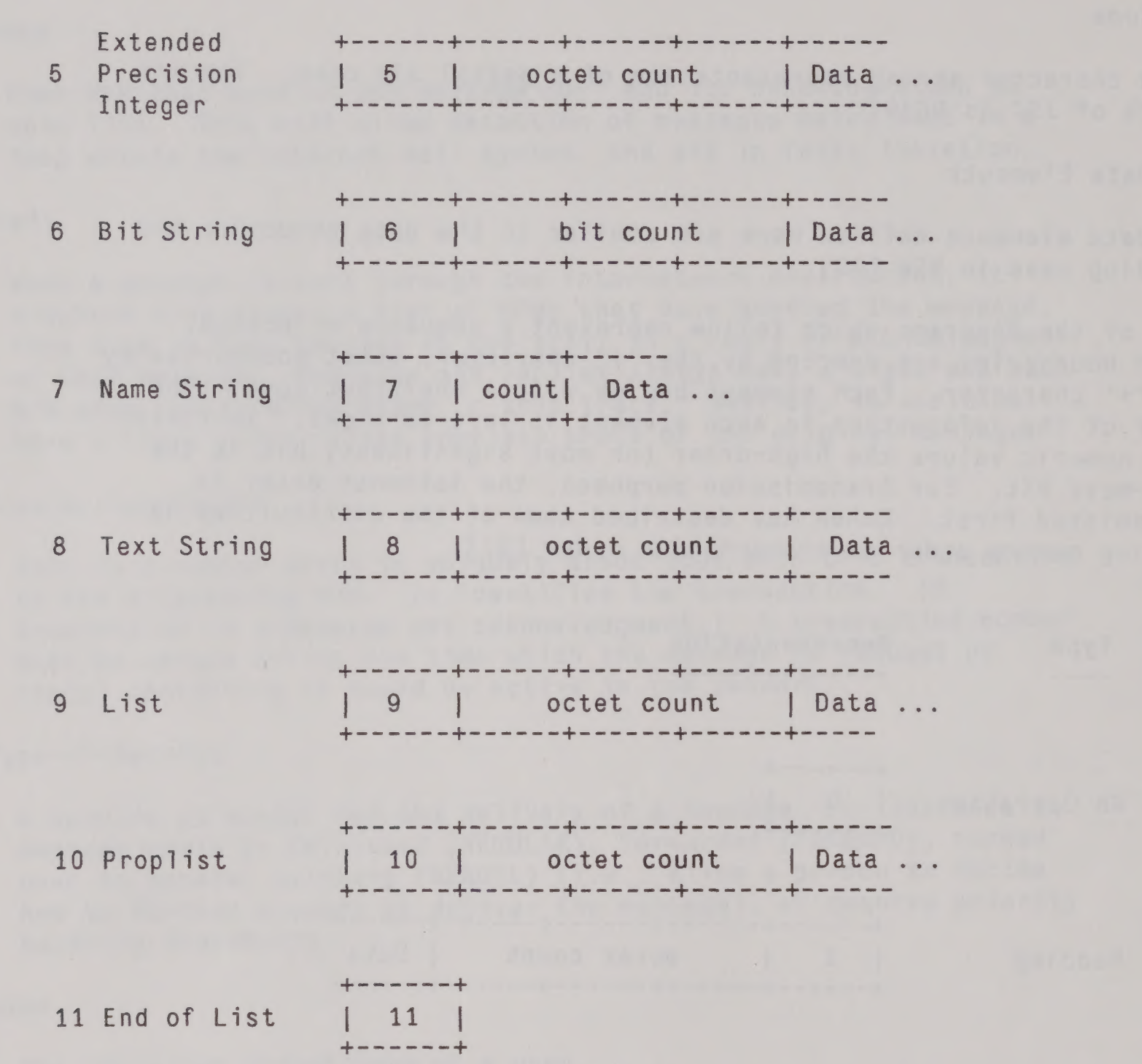


3 Index



4 Integer




5 Extended Precision Integer
5 | octet count | Data ...
6 Bit String
6 | bit count | Data ...
7 Name String
7 | count | Data ...
8 Text String
8 | octet count | Data ...
9 List
9 | octet count | Data ...
10 Proplist
10 | octet count | Data ...
11 End of List
11

Element code 0 (NOP) is an empty data element used for padding when it is necessary. It is ignored.

Element code 1 (PAD) is used to transmit large amounts of data with a message for test or padding purposes. The type-octet is followed by a three-octet count of the number of octets to follow. No action is taken with this data but the count of dummy octets must be correct to indicate the next element code.

Element code 2 (BOOLEAN) is a boolean data element. The octet following the type-octet has the value 1 for True and 0 for False.

Element code 3 (INDEX) is a 16-bit unsigned integer datum. Element code 3 occupies only 3 octets.

Element code 4 (INTEGER) is a signed 32-bit integer datum. This will always occupy five octets. Representation is two's complement.

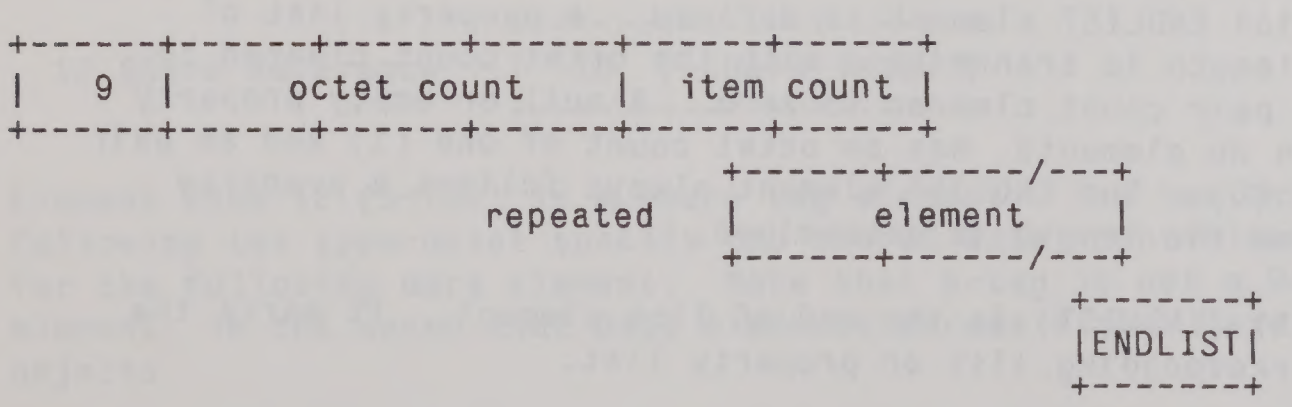
Element code 5 (EPI) is an extended precision integer. The type octet is followed by a three-octet count of the number of data octets to follow. Representation is two's complement.

Element code 6 (BITSTR) is a bit string element for binary data. The bit string is padded on the right with zeros to fill out the last octet if the bit string does not end on an octet boundary. This data type must have the bit-count in the three-octet count field instead of the number of octets.

Element code 7 (NAME) is used for the representation of character string names (or other short strings). The type octet is followed by a one-octet count of the number of characters (one per octet) to follow. Seven bit ASCII characters are used, right justified in the octet. The high order bit in the octet is zero.

Element code 8 (TEXT) is used for the representation of text. The type octet is followed by a three-octet count of the number of characters (one per octet) to follow. Seven bit ASCII characters are used, right justified in the octet. The high order bit in the octet is zero.

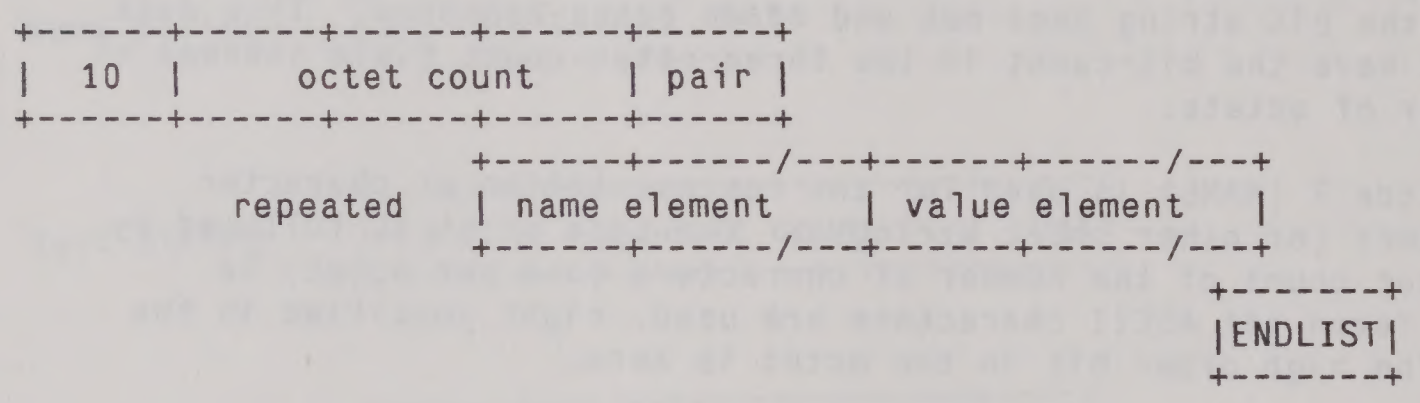
Element code 9 (LIST) can be used to create structures composed of other elements. The three-octet octet count specifies the number of octets in the whole list (i.e., the number of octets following this count field to the end of the list, not including the ENDLIST octet). The two-octet item count contains the number of elements which follow. Any element may be used including list itself.



In some situations it may not be possible to know the length of a list

until the head of it has been transmitted. To allow for this a special ENDLIST element is defined. A list of undetermined length is transmitted with the octet count cleared to zero, and the item count cleared to zero. A null or empty List, one with no elements, has an octet count of two (2) and an item count of zero (0). The ENDLIST element always follows a LIST, even when the length is determined.

Element code 10 (PROPLIST) is the Property List element. It is a special case of the list element, in which the elements are in pairs and the first element of each pair is a name. It has the following form:



The Property List structure consists of a set of unordered <name,value> pairs. The pairs are composed of a name which must be a NAME element and a value which may be any kind of element. Following the type code is a three-octet octet count of the following octets. Following the octet count is a one-octet pair count of the number of <name,value> pairs in the property list.

The name of a <name,value> pair is to be unique within the property list, that is, there shall be at most one occurrence of any particular name in one property list.

In some situations it may not be possible to know the length of a property list until the head of it has been transmitted. To allow for this the special ENDLIST element is defined. A property list of undetermined length is transmitted with the octet count cleared to zero, and the pair count cleared to zero. A null or empty property list, one with no elements, has an octet count of one (1) and an pair count of zero (0). The ENDLIST element always follows a property list, even when the length is determined.

Element code 11 (ENDLIST) is the end of list element. It marks the end of the corresponding list or property list.

Structure Sharing

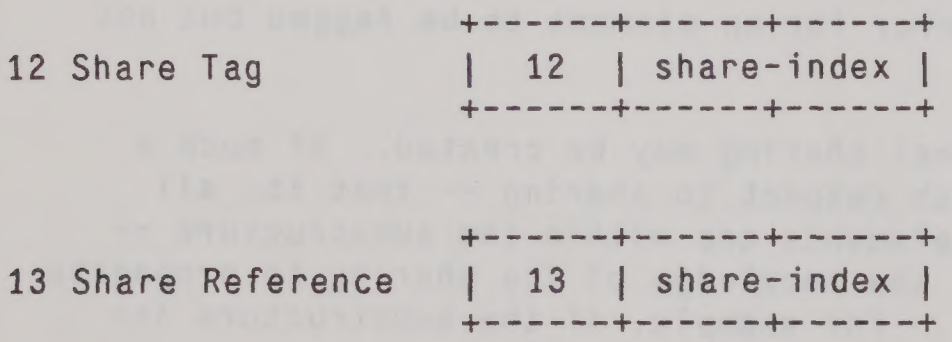
When messages are batched in message-bags for transmission, it may often be the case that the same document will be sent to more than one recipient. Since the document portion can usually be expected to be the major part of the message, much repeated data would be sent if a copy of the document for each recipient were to be shipped in the message-bag.

To avoid this redundancy, messages may be assembled in the message-bag so that actual data appears on its first occurrence and only references to it appear in later occurrences. When data is shared, the first occurrence of the data will be tagged, and later locations where the data should appear will only reference the earlier tagged location. All references to copied data point to earlier locations in the message-bag. The data to be retrieved is indicated by the tag.

This is a very general sharing mechanism. PLEASE NOTE THAT THE MPM WILL NOT SUPPORT THE FULL USE OF THIS MECHANISM. THE MPM WILL ONLY SUPPORT SHARING OF WHOLE DOCUMENTS. No other level of sharing will be supported by the MPMs.

This sharing mechanism may be used within a document as long as all references refer to tags within the same document.

Sharing is implemented by placing a share-tag on the first occurrence of the data to be shared, and placing a share-reference at the locations where copies of that data should occur.



Element code 12 (S-TAG) is a share tag element. The two octets following the type-octet specify the shared data identification code for the following data element. Note that s-tag is not a DATA element, in the sense that data elements encode higher level objects.

Element code 13 (S-REF) is a share reference element. The two

octets following the type-octet specify the referenced shared data identification code.

An example of using this mechanism is

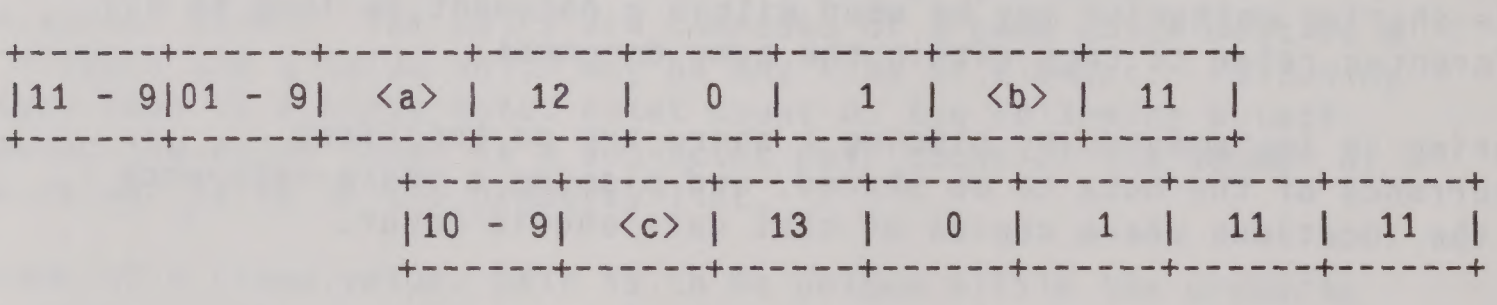
((<a>, <b>) (<c>, <b>))

could be coded as follows to share <b>

((<a>, <s-tag-1><b>) (<c>, <s-ref-1>))

To facilitate working with structures which may contain shared data, the two high-order bits of the list and property list element codes are reserved for indicating if the structure contains data to be shared or contains a reference to shared data. That is, if the high-order bit of the list or property list element code octet is set to one then the property list contains a share-reference to shared data. Or, if the second high-order bit is set to one the structure contains a share-tag for data to be shared.

The example above is now repeated in detail showing the use of the high-order bits.



It is not considered an error for an element to be tagged but not referenced.

A substructure with internal sharing may be created. If such a substructure is closed with respect to sharing -- that is, all references to its tagged elements are within the substructure -- then there is no need for the knowledge of the sharing to propagate up the hierarchy of lists. For example, if the substructure is:

00-LIST (a b c b)

which with sharing is:

11-LIST (a T1:b c R1)

When this substructure is included in a large structure the high

order bits can be reset since the substructure is closed with respect to sharing. For example:

```
00-LIST ( x 11-LIST ( a T1:b c R1 ) y )
```

Note: While sharing adds transmission and memory efficiency, it is costly in processing to separate shared elements. This is the main reason for restricting the sharing supported by the MPM. At some later time these restrictions may be eased.

It is possible to create loops, "strange loops" and "tangled hierarchies" using this mechanism [32]. The MPM will not check for such improper structures within documents, and will not deliver messages involved in such structures between documents.

If an encryption scheme is used to ensure the privacy of communication it is unlikely that any parts of the message can be shared. This is due to the fact that in most case the encryption keys will be specific between two individuals. There may be a few cases where encrypted data may be shared. For example, all the members of a committee may use a common key when acting on committee business, or in a public key scheme a document may be "signed" using the private key of the sender and inspected by anyone using the public key of the sender.

4. OTHER ISSUES

This section discusses various other issues that need to be dealt with in a computer message system.

4.1. Accounting and Billing

Accounting and billing must be performed by the MPM. The charge to the user by the message delivery system must be predictable, and so cannot depend on the actual cost of sending a particular message which incurs random delays, handling and temporary storage charges. Rather, these costs must be aggregated and charged back to the users on an average cost basis. The user of the service may be charged based on the destination or distance, the length of the message, type of service, or other parameters selected as the message is entered into the delivery system, but must not depend on essentially random handling by the system of the particular message.

This means it is pointless to have each message carry an accumulated charge (or list of charges). Rather, the MPM will keep a log of messages handled and periodically bill the originators of those messages.

It seems that the most reasonable scheme is to follow the practice of the international telephone authorities. In such schemes the authority where the message originates bills the user of the service for the total charge. The authorities assist each other in providing the international message transfer and the authorities periodically settle any differences in accounts due to an imbalance in international traffic.

Thus the MPMs will keep logs of messages handled and will periodically charge their neighboring MPM for messages handled for them. This settlement procedure is outside the message system and between the administrators of the MPMs.

As traffic grows it will be impractical to log every message individually. It will be necessary to establish categories of messages (e.g., short, medium, large) and only count the number in each category.

The MPM at the source of the message will have a local means of identifying the user to charge for the message delivery service. The relay and destination MPMs will know which neighbor MPMs to charge (or settle with) for delivery of their messages.

4.2. Addressing and Routing

The mailbox provides for many types of address information. The MPMs in the ARPA internet can most effectively use the internet address [2]. The use of other address information is not yet very clear. Some thoughts on addressing issues may be found in the references [33,34,35].

An MPM sometimes must make a routing decision when it is acting as a relay-MPM (or source MPM). It must be able to use the information from the mailbox to determine to which of its neighbor MPMs to send the message. One way this might be implemented is to have a table of destination networks with corresponding neighbor MPM identifiers to use for routing toward that network.

It is not expected that such routing tables would be very dynamic. Changes would occur only when new MPMs came into existence or MPMs went out of service for periods of days.

Even with relatively slowly changing routing information the MPMs need an automatic mechanism for adjusting their routing tables. The routing problem here is quite similar to the problem of routing in a network of packet switches such as the ARPANET IMPs or a set of internet gateways. A great deal of work has been done on such problems and many simple schemes have been found faulty. There are details of these procedures which may become troublesome when the number of nodes grows beyond a certain point or the frequency of update exchanges gets large.

A basic routing scheme is to have a table of <network-name, mpm-identifier> pairs. The MPM could look up the network name found in the mailbox of the message and determine the internet mpm-identifier of the next MPM to which to route the message. To permit automatic routing updates another column would be added to indicate the distance to the destination. This could be measured in several ways, for example, the number of relay MPM (or hops) to the final destination. In this case each entry in the table is a triple of <network-name, mpm-identifier, distance>.

To update the routing information when changes occur an MPM updates its table. It then sends to each next MPM in its table a table of pairs <network-name, distance>, which say in effect "I can get a message to each of these networks with "cost" distance." An MPM which receives such an update will add to all the distances the distance to the MPM sending the update (e.g., one hop) and compare the information with its own table.

If the update information shows that the distance to a destination network is now smaller via the MPM which sent the update, the MPM changes its own table to reflect the better route, and the new distance. If the MPM has made changes in its table it sends update information to all the MPMs listed as next-MPMs in its table.

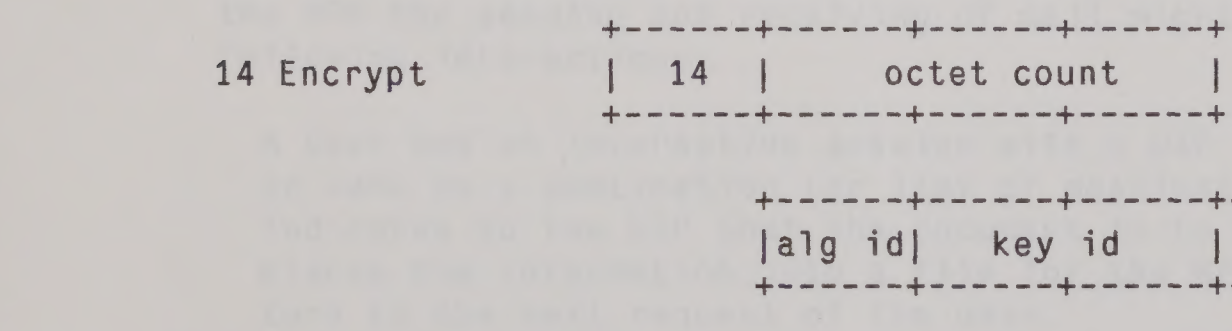
One further feature is that when a new network comes into existence an entry must be added to the table in each MPM. The MPMs should therefore expect the case that update information may contain entries which are new networks, and in such an event add these entries to their own tables.

When a new MPM comes into existence it will have an initial table indicating that it is a good route (short distance) to the network it is in, and will have entries for a few neighbor networks. It will send an initial "update" to those neighbor MPMs which will respond with more complete tables, thus informing the new MPM of routes to many networks.

This routing update mechanism is a simple minded scheme and may have to be replaced as the system of MPMs grows. In addition it ignores the opportunity for MPMs to use other information (besides destination network name) for routing. MPMs may have tables that indicate next-MPMs based on city, telephone number, organization, or other categories of information.

4.3. Encryption

It is straightforward to add the capability to have the document portion of messages either wholly or partially encrypted. An additional basic data element is defined to carry encrypted data. The data within this element may be composed of other elements, but that could only be perceived after the data was decrypted.



Element code 14 (ENCRYPT) is used to encapsulate encrypted data. The format is the one-octet type code, the three-octet octet count, a one-octet algorithm identifier, a two-octet key identifier, and count octets of data. Use of this element indicates that the data it

contains is encrypted. The encryption scheme is indicated by the algorithm identifier, and the key used is indicated by the key identifier (this is not the key itself). The NBS Data Encryption Standard (DES) [36], public key encryption [37,38,39], or other schemes may be used.

To process this data element, the user is asked for the appropriate key and the data can then be decrypted. The data thus revealed will be in the form of complete data element fields. Encryption cannot occur over a partial field. The revealed data is then processed normally.

Note that there is no reason why all fields of a document could not be encrypted including all document header information such as From, Date, etc.

5. THE MPM: A POSSIBLE ARCHITECTURE

The heart of the internet message system is the MPM which is responsible for routing and delivering messages. Each network must have at least one MPM. These MPMs are logically connected together, and internet mail is always transferred along logical channels between them. The MPMs interface with existing local message systems.

Since the local message system may be very different from the internet system, special programs may be necessary to convert incoming internet messages to the local format. Likewise, messages outgoing to other networks may be converted to the internet format and sent via the MPMs.

5.1. Interfaces

User Interface

It is assumed that the interface between the MPM and the UIP provides for passing data structures which represent the document portion of the message. In addition, this interface must pass the delivery address information (which becomes the information in the mailbox field of the command). It is assumed that the information is passed between the UIP and the MPM via shared files, but this is not the only possible mechanism. These two processes may be more strongly coupled (e.g., by sharing memory), or less strongly coupled (e.g., by communicating via logical channels).

When a UIP passes a document and a destination address to the MPM, the MPM assigns a transaction-number and forms a message to send. The MPM must record the relationship between the transaction-number, the document, and the UIP, so that it can inform the UIP about the outcome of the delivery attempt for that document when the acknowledgment message is received at some later time.

Assuming a file passing mode of communication between the UIP and the MPM the sending and receiving of mail might involve the following interactions:

A user has an interactive session with a UIP to compose a document to send to a destination (or list of destinations). When the user indicates to the UIP that the document is to be sent, the UIP places the information into a file for the MPM. The UIP may then turn to the next request of the user.

The MPM finds the file and extracts the the information. It creates a message, assigning a transaction-number and forming a deliver command. The MPM records the UIP associated with this message. The MPM sends the message toward the destination.

When the MPM receives a deliver message from another MPM addressed to a user in its domain, it extracts the document and puts it into a file for the UIP associated with the destination user. The MPM also sends an acknowledge message to the originating MPM.

When the MPM receives an acknowledgment for a message it sent, the MPM creates a notification for the associated UIP and places it in a file for that UIP.

The format of these files is up to each UIP/MPM interface pair. One reasonable choice is to use the same data structures used in the MPM-MPM communication.

Communication Interface

It is assumed here that the MPMs use an underlying communication system, and TCP [3] has been taken as the model. In particular, the MPM is assumed to be listening for a TCP connection on a TCP port, i.e., it is a server process. The port is either given explicitly in the mpm-identifier or takes the default vaule 45 (55 octal) [4]. Again, this is not intended to limit the implementation choices; other forms of interprocess communication are allowed, and other types of physical interconnection are permitted. One might even use dial telephone calls to interconnect MPMs (using suitable protocols to provide reliable communication) [12,19,20,21].

5.2. The MPM Organization

Messages in the internet mail system are transmitted in lists called message-bags (or simply bags), each bag containing one or more messages. Each MPM is expected to implement functions which will allow it to deliver local messages it receives and to forward non-local ones to other MPMs presumably closer to the message's destination.

Loosely, each MPM can be separated into six components:

1--Acceptor

Receives incoming message-bags, from other MPMs, from UIPs, or from conversion programs.

2--Message-Bag Processor

Splits a bag into these three portions:

a. Local Host Messages
b. Local Net Messages
c. Foreign Net Messages

3--Local Host Delivery

Delivers local host messages, may call on conversion program.

4--Local Net Delivery

Delivers local net messages, may call on conversion program.

5--Foreign Net Router

Forms message-bags for transmission to other MPMs and determines the first step in the route.

6--Foreign Net Sender

Activates transmission channels to other MPMs and sends message-bags to foreign MPMs.

If the local net message system uses the protocol of the MPMs, then there need be no distinction between local net and foreign net delivery procedures.

All of these components can be thought of as independent. The function of the Acceptor is to await incoming message-bags and to insert them into the Bag-Input Queue.

The Bag-Input queue is read by the message-bag Processor which will separate and deliver suitable portions of the message-bags it retrieves from the queue to one of three queues:

a. Local Host Queue
b. Local Net Queue
c. Foreign Net Queue

When an MPM has a message to send to another MPM, it must add its own handling-stamp to the trace field of the command. The trace then becomes a record of the route the message has taken. An MPM should examine the trace field to see if the message is in a routing loop. All commands require the return of the trace as a trail in the matching reply command.

All of these queues have as elements complete message-bags created by selecting messages from the input message-bags.

The Local Host queue serves as input to the Local Host Delivery process. This component is responsible for delivering messages to its local host. It may call on a conversion program to reformat the messages into a form the local protocol will accept. This will probably involve such things as copying shared information.

The Local Net queue serves as input to the Local Net Delivery process. This component is responsible for delivering messages to other hosts on its local net. It must be capable of handling whatever error conditions the local net might return, and should include the ability to retransmit. It may call on a conversion program to reformat the messages into a form the local protocol will accept. This will probably involve such things as copying shared information.

The other two processes are more closely coupled. The Foreign Net Router takes its input bags from the Foreign Net Queue. From the internal information it contains, it determines which of the MPMs to which it is connected should receive the bag.

It then places the bag along with the routing information into the Send Mail Queue. The Foreign Net Sender retrieves it from that queue and transmits it across a channel to the intended foreign MPM. The Sender aggregates messages to the same next MPM into a bag.

The Foreign Net Router should be capable of receiving external input to its routing information table. This may come from the Foreign Net Sender in the case of a channel going down, requiring a decision to either postpone delivery or to determine a new route. The Router is responsible for maintaining sufficient information to determine where to send any incoming message-bag.

Forwarding

An MPM may have available information on the correct mailboxes of users which are not at its location. This information, called a forwarding data base, may be used to return the correct address in response to a probe command, or to actually forward a deliver command (if allowed by the type of service).

Because such forwarding may cause the route of a message to pass through an MPM already on the trace of this message, only the portion of the trace back to the most recent forward action should be used for loop detection by a relay relaying MPM, and only the forward action entries in the trace should be checked by a forwarding MPM.

Implementation Recommendations

Transaction numbers can be assigned sequentially, with wrap around when the highest value is reached. This should ensure that no message with a particular transaction number from this source is in the network when another instance of this transaction number is chosen.

The processing to separate shared elements when the routes of the shared elements diverge while still preserving the sharing possible appears to be an O(N*M**2) operation where N is the number of distinct objects in a message which may be shared across message boundaries and M is the number of messages in the bag.

Also note that share-tags may be copied into separate message bags which are not referenced. These could be removed with another pass over the message bag.

6. EXAMPLES & SCENARIOS

Example 1: Message Format

Suppose we want to send the following message:

```
Date: 1979-03-29-11:46-08:00
From: Jon Postel <Postel@ISIE>
Subject: Meeting Thursday
To: Danny Cohen <Cohen@USC-ISIB>
CC: Linda

Danny:

Please mark your calendar for our meeting Thursday at 3 pm.

--jon.
```

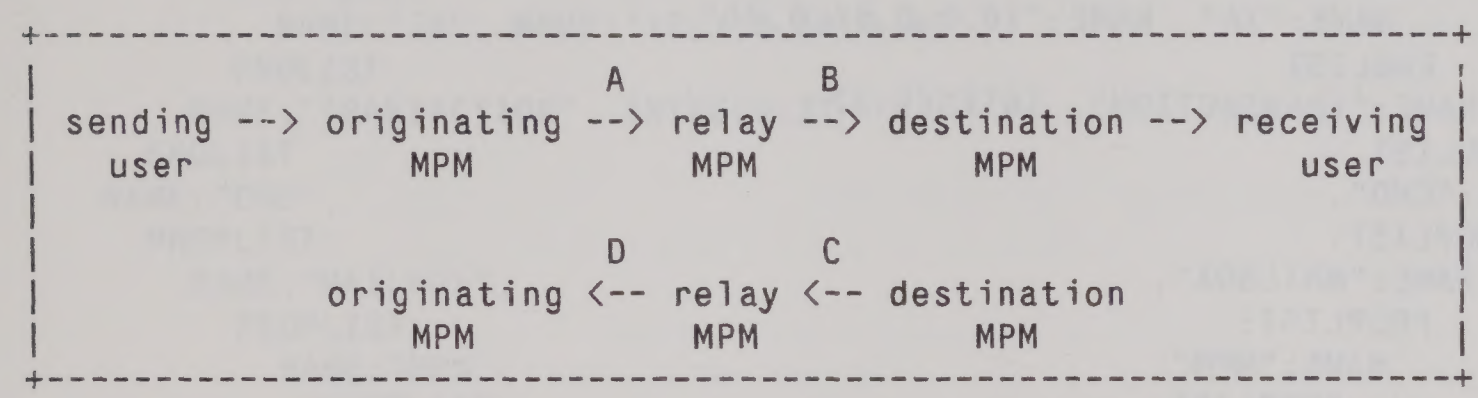
It will be encoded in the structured format. The following will present successive steps in the top down generation of this message. The actual document above will not be shown in the coded form.

```
1.  message

2.  (identification, command, document)

3.  (ID:(mpm-identifier, transaction-number),
     CMD:(MAILBOX:mailbox, OPERATION:operation,
                                          arguments, TRACE:trace),
     DOC:<<document>>)

4.  (ID:(mpm-identifier, transaction-number),
     CMD:(MAILBOX:mailbox, OPERATION:operation,
                              TYPE-OF-SERVICE:regular, TRACE:trace),
     DOC:<<document>>)

5.  (ID:(MPM:(IA:12,1,0,52,0,45), TRANSACTION:37),
     CMD:(MAILBOX:(MPM:(IA:12,3,0,52,0,45),
                   NET:ARPA,
                   HOST:ISIB,
                   PORT:45,
                   USER:Cohen),
          OPERATION:DELIVER,
          TYPE-OF-SERVICE:REGULAR,
          TRACE:(MPM:(IA:12,1,0,52,0,45)
                 DATE:1979-03-29-11:46-08:00,
                 ACTION:ORIGIN)),
     DOC:<<document>>)
```

6.
```
PROPLIST:(
  ID:PROPLIST:(
       MPM:PROPLIST:(
             IA:12,1,0,52,0,45),
          ENDLIST
       TRANSACTION:37)
     ENDLIST,

  CMD:PROPLIST(
       MAILBOX:(PROPLIST:(
                  MPM:PROPLIST(
                        IA:12,3,0,52,0,45),
                     ENDLIST
                  NET:ARPA,
                  HOST:ISIB,
                  PORT:45,
                  USER:Cohen ),
                ENDLIST
       OPERATION:DELIVER,
       TYPE-OF-SERVICE:REGULAR,
       TRACE:(PROPLIST:MPM:
                (PROPLIST:
                   IA:12,1,0,52,0,45)
                  ENDLIST
                DATE:1979-03-29-11:46-08:00,
                ACTION:ORIGIN)),
              ENDLIST
    ENDLIST
  DOC:<<document>>)
ENDLIST
```

Example 2: Delivery and Acknowledgment

The following are four views of the message of example 1 during the successive transmission from the origination MPM, through a relay MPM, to the destination MPM, and the return of the acknowledgment, through a relay MPM, to the originating MPM.



Transmission Path

Figure 6.

A. Between the originating MPM and the relay MPM.

```
PROPLIST:
  NAME:"ID",
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:"10,1,0,52,0,45"
        ENDLIST
      NAME:"TRANSACTION", INTEGER:37
    ENDLIST
  NAME:"CMD",
    PROPLIST:
      NAME:"MAILBOX",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", NAME:"10,3,0,52,0,45"
            ENDLIST
          NAME:"NET", NAME:"ARPA"
          NAME:"HOST", NAME:"ISIB"
          NAME:"PORT", NAME:"45"
          NAME:"USER", NAME:"Cohen"
        ENDLIST
      NAME:"OPERATION", NAME:"DELIVER"
      NAME:"TYPE-OF-SERVICE", NAME:"REGULAR"
      NAME:"TRACE",
        LIST:
          PROPLIST:
            NAME:"MPM",
              PROPLIST:
                NAME:"IA", NAME:"10,1,0,52,0,45"
              ENDLIST
            NAME:"DATE", NAME:"1979-03-29-11:47.5-08:00"
            NAME:"ACTION", NAME:"ORIGIN"
          ENDLIST
        ENDLIST
    ENDLIST
  NAME:"DOC", <<document>>
ENDLIST
```

B. Between the relay MPM and the destination MPM.

```
PROPLIST:
  NAME:"ID",
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:"10,1,0,52,0,45"
        ENDLIST
      NAME:"TRANSACTION", INTEGER:37
    ENDLIST
  NAME:"CMD",
    PROPLIST:
      NAME:"MAILBOX",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", NAME:"10,3,0,52,0,45"
            ENDLIST
          NAME:"NET", NAME:"ARPA"
          NAME:"HOST", NAME:"ISIB"
          NAME:"PORT", NAME:"45"
          NAME:"USER", NAME:"Cohen"
        ENDLIST
      NAME:"OPERATION", NAME:"DELIVER"
      NAME:"TYPE-OF-SERVICE", NAME:"REGULAR"
      NAME:"TRACE",
        LIST:
          PROPLIST:
            NAME:"MPM",
              PROPLIST:
                NAME:"IA", NAME:"10,1,0,52,0,45"
              ENDLIST
            NAME:"DATE", NAME:"1979-03-29-11:47.5-08:00"
            NAME:"ACTION", NAME:"ORIGIN"
          ENDLIST
          PROPLIST:
            NAME:"MPM",
              PROPLIST:
                NAME:"IA", NAME:"10,2,0,52,0,45"
              ENDLIST
            NAME:"DATE", NAME:"1979-03-29-11:48-08:00"
            NAME:"ACTION", NAME:"RELAY"
          ENDLIST
        ENDLIST
    ENDLIST
  NAME:"DOC", <<document>>
```

```
    ENDLIST
```

C. Between the destination MPM and the relay MPM.

```
    PROPLIST:
      NAME:"ID",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", NAME:"10,3,0,52,0,45"
            ENDLIST
          NAME:"TRANSACTION", INTEGER:1993
        ENDLIST
      NAME:"CMD",
        PROPLIST:
          NAME:"MAILBOX",
            PROPLIST:
              NAME:"MPM",
                PROPLIST:
                  NAME:"IA", INTEGER:"10,1,0,52,0,45"
                ENDLIST
              NAME:"NET", NAME:"ARPA"
              NAME:"HOST", NAME:"ISIE"
              NAME:"PORT", NAME:"45"
              NAME:"USER", NAME:"*MPM*"
            ENDLIST
          NAME:"OPERATION", NAME:"ACKNOWLEDGE"
          NAME:"REFERENCE",
            PROPLIST:
              NAME:"MPM",
                PROPLIST:
                  NAME:"IA", NAME:"10,1,0,52,0,45"
                ENDLIST
              NAME:"TRANSACTION", INTEGER:37
            ENDLIST
          NAME:"ADDRESS",
            PROPLIST:
              NAME:"MPM",
                PROPLIST:
                  NAME:"IA", INTEGER:"10,3,0,52,0,45"
                ENDLIST
              NAME:"USER", NAME:"Cohen"
            ENDLIST
          NAME:"TYPE-OF-SERVICE", NAME:"REGULAR"
          NAME:"ERROR-CLASS", INDEX:0
          NAME:"ERROR-STRING", NAME:"Ok"
          NAME:"TRAIL",
```

```
LIST:
  PROPLIST:
    NAME:"MPM",
      PROPLIST:
        NAME:"IA", NAME:"10,1,0,52,0,45"
      ENDLIST
    NAME:"DATE", NAME:"1979-03-29-11:47.5-08:00"
    NAME:"ACTION", NAME:"ORIGIN"
  ENDLIST
  PROPLIST:
    NAME:"MPM",
      PROPLIST:
        NAME:"IA", NAME:"10,2,0,52,0,45"
      ENDLIST
    NAME:"DATE", NAME:"1979-03-29-11:48-08:00"
    NAME:"ACTION", NAME:"RELAY"
  ENDLIST
  PROPLIST:
    NAME:"MPM",
      PROPLIST:
        NAME:"IA", NAME:"10,3,0,52,0,45"
      ENDLIST
    NAME:"DATE", NAME:"1979-03-29-11:51.567-08:00"
    NAME:"ACTION", NAME:"DESTINATION"
  ENDLIST
 NAME:"TRACE",
  LIST:
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:"10,3,0,52,0,45"
        ENDLIST
      NAME:"DATE", NAME:"1979-03-29-11:52-08:00"
      NAME:"ACTION", NAME:"ORIGIN"
    ENDLIST
  ENDLIST
ENDLIST
```

D. Between the relay MPM and the originating MPM.

```
PROPLIST:
  NAME:"ID",
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:"10,3,0,52,0,45"
        ENDLIST
      NAME:"TRANSACTION", INTEGER:1993
    ENDLIST
  NAME:"CMD",
    PROPLIST:
      NAME:"MAILBOX",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", INTEGER:"10,1,0,52,0,45"
            ENDLIST
          NAME:"NET", NAME:"ARPA"
          NAME:"HOST", NAME:"ISIE"
          NAME:"PORT", NAME:"45"
          NAME:"USER", NAME:"*MPM*"
        ENDLIST
      NAME:"OPERATION", NAME:"ACKNOWLEDGE"
      NAME:"REFERENCE",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", NAME:"10,1,0,52,0,45"
            ENDLIST
          NAME:"TRANSACTION", INTEGER:37
        ENDLIST
      NAME:"ADDRESS",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", INTEGER:"10,3,0,52,0,45"
            ENDLIST
          NAME:"USER", NAME:"Cohen"
        ENDLIST
      NAME:"TYPE-OF-SERVICE", NAME:"REGULAR"
      NAME:"ERROR-CLASS", INDEX:0
      NAME:"ERROR-STRING", NAME:"Ok"
      NAME:"TRAIL",
        LIST:
          PROPLIST:
```

```
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:"10,1,0,52,0,45"
        ENDLIST
      NAME:"DATE", NAME:"1979-03-29-11:47.5-08:00"
      NAME:"ACTION", NAME:"ORIGIN"
    ENDLIST
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:"10,2,0,52,0,45"
        ENDLIST
      NAME:"DATE", NAME:"1979-03-29-11:48-08:00"
      NAME:"ACTION", NAME:"RELAY"
    ENDLIST
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:"10,3,0,52,0,45"
        ENDLIST
      NAME:"DATE", NAME:"1979-03-29-11:51.567-08:00"
      NAME:"ACTION", NAME:"DESTINATION"
        ENDLIST
      ENDLIST
    NAME:"TRACE",
      LIST:
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", NAME:"10,3,0,52,0,45"
            ENDLIST
          NAME:"DATE", NAME:"1979-03-29-11:52-08:00"
          NAME:"ACTION", NAME:"ORIGIN"
        ENDLIST
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", NAME:"10,2,0,52,0,45"
            ENDLIST
          NAME:"DATE", NAME:"1979-03-29-11:52.345-08:00"
          NAME:"ACTION", NAME:"RELAY"
        ENDLIST
      ENDLIST
  ENDLIST
```

7. SPECIFICATION SUMMARY

7.1. Message Fields

All keywords used in this protocol are to be recognized independent of case.

```
action: NAME (one of)
  "ORIGIN" | "RELAY" | "FORWARD" | "DESTINATION"

address: PROPLIST (one of)

  NAME: "MPM", <mpm-identifier>
  NAME: "USER", <user>

    or

  NAME: "NET", <net>
  NAME: "HOST", <host>
  NAME: "PORT", <port>
  NAME: "USER", <user>

answer: BOOLEAN

city: NAME

command: PROPLIST
  NAME: "MAILBOX", <mailbox>
  NAME: "OPERATION", <operation>
  <<arguments>>
  NAME: "ERROR-CLASS", <error-class>    (only in replies)
  NAME: "ERROR-STRING", <error-string>  (only in replies)
  NAME: "TRACE", <trace>

country: NAME

document: <<document>>

error-class: INDEX

error-string: NAME

host: NAME
```

```
handling-stamp: PROPLIST
  NAME: "MPM", <mpm-identifier>
  NAME: "DATE", <date>
  NAME: "ACTION", <action>

identification: LIST
  NAME: "MPM", <mpm-identifier>
  NAME: "TRANSACTION", <transaction-number>

internet-address: NAME

mailbox:  PROPLIST (some of)
  NAME: "MPM", <mpm-identifier>
  NAME: "NET", <net>
  NAME: "HOST", <host>
  NAME: "PORT", <port>
  NAME: "USER", <user>
  NAME: "ORG", <organization>
  NAME: "CITY", <city>
  NAME: "STATE", <state>
  NAME: "COUNTRY", <country>
  NAME: "ZIP", <zip-code>
  NAME: "PHONE", <phone-number>
  <<other-items>>

message: PROPLIST
  NAME: "ID", <identification>
  NAME: "CMD", <command>
  NAME: "DOC", <document> (only in deliver)

mpm-identifier: PROPLIST (one of)

  NAME: "IA", <internet-address>

    or

  NAME: "X121", <x121-address>

net: NAME

operation: NAME (one of)
    "DELIVER" | "ACKNOWLEDGE
  | "PROBE"   | "RESPONSE
  | "CANCEL"  | "CANCELED"

organization: NAME

phone-number: NAME
```

```
port: NAME

state: NAME

trace: LIST
  <handling-stamp>
  ...

trail: LIST
  <handling-stamp>
  ...

transaction-number: INTEGER

type-of-service: NAME (one or more of)
  "REGULAR" | "FORWARD" | "GENDEL" | "PRIORITY"

user: NAME

x121-address: NAME

zip-code: NAME
```

7.2. Deliver Message

```
PROPLIST:
  NAME:"ID",
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:<internet-address>
        ENDLIST
      NAME:"TRANSACTION", INTEGER:<transaction-number>
    ENDLIST
  NAME:"CMD",
    PROPLIST:
      NAME:"MAILBOX",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", INTEGER:<internet-address>
            ENDLIST
          NAME:"NET", NAME:<net>
          NAME:"HOST", NAME:<host>
          NAME:"PORT", NAME:<port>
          NAME:"USER", NAME:<user>
          NAME:"ORG", NAME:<organization>
          NAME:"CITY", NAME:<city>
          NAME:"STATE", NAME:<state>
          NAME:"COUNTRY", NAME:<country>
          NAME:"ZIP", NAME:<zip-code>
          NAME:"PHONE", NAME:<phone-number>
          <<other-items>>
        ENDLIST
      NAME:"OPERATION", NAME:"DELIVER"
      NAME:"TYPE-OF-SERVICE", NAME:<type-of-service>
      NAME:"TRACE",
        LIST:
          PROPLIST:
            NAME:"MPM",
              PROPLIST:
                NAME:"IA", INTEGER:<internet-address>
              ENDLIST
            NAME:"DATE", NAME:<date>
            NAME:"ACTION", NAME:<action>
          ENDLIST
          ...
        ENDLIST
    ENDLIST
  NAME:"DOC", <<document>>
ENDLIST
```

7.3. Acknowledge Message

```
PROPLIST:
  NAME:"ID",
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:<internet-address>
        ENDLIST
      NAME:"TRANSACTION", INTEGER:<transaction-number>
    ENDLIST
  NAME:"CMD",
    PROPLIST:
      NAME:"MAILBOX",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", INTEGER:<internet-address>
            ENDLIST
          NAME:"USER", NAME:"*MPM*"
          NAME:"NET", NAME:<net>
          NAME:"PORT", NAME:<port>
          NAME:"HOST", NAME:<host>
        ENDLIST
      NAME:"OPERATION", NAME:"ACKNOWLEDGE"
      NAME:"REFERENCE",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", NAME:<internet-address>
            ENDLIST
          NAME:"TRANSACTION", INTEGER:<transaction-number>
        ENDLIST
      NAME:"ADDRESS",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", INTEGER:<internet-address>
            ENDLIST
          NAME:"USER", NAME:<user>
        ENDLIST
      NAME:"TYPE-OF-SERVICE", NAME:<type-of-service>
      NAME:"ERROR-CLASS", INDEX:<error-class>
      NAME:"ERROR-STRING", NAME:<error-string>
      NAME:"TRAIL",
        LIST:
          PROPLIST:
            NAME:"MPM",
```

```
                PROPLIST:
                  NAME:"IA", INTEGER:<internet-address>
                ENDLIST
              NAME:"DATE", NAME:<date>
              NAME:"ACTION", NAME:<action>
            ENDLIST
            ...
          ENDLIST
        NAME:"TRACE",
          LIST:
            PROPLIST:
              NAME:"MPM",
                PROPLIST:
                  NAME:"IA", INTEGER:<internet-address>
                ENDLIST
              NAME:"DATE", NAME:<date>
              NAME:"ACTION", NAME:<action>
            ENDLIST
            ...
          ENDLIST
      ENDLIST
  ENDLIST
```

7.4. Probe Message

```
PROPLIST:
  NAME:"ID",
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:<internet-address>
        ENDLIST
      NAME:"TRANSACTION", INTEGER:<transaction-number>
    ENDLIST
  NAME:"CMD",
    PROPLIST:
      NAME:"MAILBOX",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", INTEGER:<internet-address>
            ENDLIST
          NAME:"NET", NAME:<net>
          NAME:"HOST", NAME:<host>
          NAME:"PORT", NAME:<port>
          NAME:"USER", NAME:<user>
          NAME:"ORG", NAME:<organization>
          NAME:"CITY", NAME:<city>
          NAME:"STATE", NAME:<state>
          NAME:"COUNTRY", NAME:<country>
          NAME:"ZIP", NAME:<zip-code>
          NAME:"PHONE", NAME:<phone-number>
          <<other-items>>
        ENDLIST
      NAME:"OPERATION", NAME:"PROBE"
      NAME:"TRACE",
        LIST:
          PROPLIST:
            NAME:"MPM",
              PROPLIST:
                NAME:"IA", INTEGER:<internet-address>
              ENDLIST
            NAME:"DATE", NAME:<date>
            NAME:"ACTION", NAME:<action>
          ENDLIST
          ...
        ENDLIST
    ENDLIST
ENDLIST
```

7.5. Response Message

```
PROPLIST:
  NAME:"ID",
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:<internet-address>
        ENDLIST
      NAME:"TRANSACTION", INTEGER:<transaction-number>
    ENDLIST
  NAME:"CMD",
    PROPLIST:
      NAME:"MAILBOX",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", INTEGER:<internet-address>
            ENDLIST
          NAME:"NET", NAME:<net>
          NAME:"HOST", NAME:<host>
          NAME:"PORT", NAME:<port>
          NAME:"USER", NAME:"*MPM*"
        ENDLIST
      NAME:"OPERATION", NAME:"RESPONSE"
      NAME:"REFERENCE",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", NAME:<internet-address>
            ENDLIST
          NAME:"TRANSACTION", INTEGER:<transaction-number>
        ENDLIST
      NAME:"ADDRESS",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", INTEGER:<internet-address>
            ENDLIST
          NAME:"USER", NAME:<user>
        ENDLIST
      NAME:"ERROR-CLASS", INDEX:<error-class>
      NAME:"ERROR-STRING", NAME:<error-string>
      NAME:"TRAIL",
        LIST:
          PROPLIST:
            NAME:"MPM",
              PROPLIST:
```

```
                NAME:"IA", INTEGER:<internet-address>
              ENDLIST
            NAME:"DATE", NAME:<date>
            NAME:"ACTION", NAME:<action>
          ENDLIST
          ...
        ENDLIST
      NAME:"TRACE",
        LIST:
          PROPLIST:
            NAME:"MPM",
              PROPLIST:
                NAME:"IA", INTEGER:<internet-address>
              ENDLIST
            NAME:"DATE", NAME:<date>
            NAME:"ACTION", NAME:<action>
          ENDLIST
          ...
        ENDLIST
    ENDLIST
ENDLIST
```

7.6. Cancel Message

```
PROPLIST:
  NAME:"ID",
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:<internet-address>
        ENDLIST
      NAME:"TRANSACTION", INTEGER:<transaction-number>
    ENDLIST
  NAME:"CMD",
    PROPLIST:
      NAME:"MAILBOX",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", INTEGER:<internet-address>
            ENDLIST
          NAME:"NET", NAME:<net>
          NAME:"HOST", NAME:<host>
          NAME:"PORT", NAME:<port>
          NAME:"USER", NAME:<user>
          NAME:"ORG", NAME:<organization>
          NAME:"CITY", NAME:<city>
          NAME:"STATE", NAME:<state>
          NAME:"COUNTRY", NAME:<country>
          NAME:"ZIP", NAME:<zip-code>
          NAME:"PHONE", NAME:<phone-number>
          <<other-items>>
    ENDLIST
  NAME:"OPERATION", NAME:"CANCEL"
  NAME:"REFERENCE",
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:<internet-address>
        ENDLIST
      NAME:"TRANSACTION", INTEGER:<transaction-number>
    ENDLIST
  NAME:"TRACE",
    LIST:
      PROPLIST:
        NAME:"MPM",
          PROPLIST:
            NAME:"IA", INTEGER:<internet-address>
          ENDLIST
        NAME:"DATE", NAME:<date>
```

```
            NAME:"ACTION", NAME:<action>
          ENDLIST
          ...
        ENDLIST
    ENDLIST
ENDLIST
```

7.7. Canceled Message

```
PROPLIST:
  NAME:"ID",
    PROPLIST:
      NAME:"MPM",
        PROPLIST:
          NAME:"IA", NAME:<internet-address>
        ENDLIST
      NAME:"TRANSACTION", INTEGER:<transaction-number>
    ENDLIST
  NAME:"CMD",
    PROPLIST:
      NAME:"MAILBOX",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", INTEGER:<internet-address>
            ENDLIST
          NAME:"NET", NAME:<net>
          NAME:"HOST", NAME:<host>
          NAME:"PORT", NAME:<port>
          NAME:"USER", NAME:"*MPM*"
        ENDLIST
      NAME:"OPERATION", NAME:"CANCELED"
      NAME:"REFERENCE",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", NAME:<internet-address>
            ENDLIST
          NAME:"TRANSACTION", INTEGER:<transaction-number>
        ENDLIST
      NAME:"ADDRESS",
        PROPLIST:
          NAME:"MPM",
            PROPLIST:
              NAME:"IA", INTEGER:<internet-address>
            ENDLIST
          NAME:"USER", NAME:<user>
        ENDLIST
      NAME:"ERROR-CLASS", INDEX:<error-class>
      NAME:"ERROR-STRING", NAME:<error-string>
      NAME:"TRAIL",
        LIST:
          PROPLIST:
            NAME:"MPM",
              PROPLIST:
```

```
                NAME:"IA", INTEGER:<internet-address>
              ENDLIST
            NAME:"DATE", NAME:<date>
            NAME:"ACTION", NAME:<action>
          ENDLIST
          ...
        ENDLIST
      NAME:"TRACE",
        LIST:
          PROPLIST:
            NAME:"MPM",
              PROPLIST:
                NAME:"IA", INTEGER:<internet-address>
              ENDLIST
            NAME:"DATE", NAME:<date>
            NAME:"ACTION", NAME:<action>
          ENDLIST
          ...
        ENDLIST
    ENDLIST
ENDLIST
```

7.8. Data Element Summary

CODE	NAME	STRUCTURE	LENGTH
0	NOP	CODE(1)	1
1	PAD	CODE(1),COUNT(3),DATA(C)	C+4
2	BOOLEAN	CODE(1),TRUE-FALSE(1)	2
3	INDEX	CODE(1),INDEX(2)	3
4	INTEGER	CODE(1),INTEGER(4)	5
5	EPI	CODE(1),COUNT(3),INTEGER(C)	C+4
6	BITSTR	CODE(1),COUNT(3),BITS(C/8)	C/8+4
7	NAME	CODE(1),COUNT(1),NAME(C)	C+2
8	TEXT	CODE(1),COUNT(3),TEXT(C)	C+4
9	LIST	CODE(1),COUNT(3),ITEMS(2),DATA(C-2)	C+4
10	PROPLIST	CODE(1),COUNT(3),PAIRS(1),DATA(C-1)	C+4
11	ENDLIST	CODE(1)	1
12	S-TAG	CODE(1),INDEX(2)	3
13	S-REF	CODE(1),INDEX(2)	3
14	ENCRYPT	CODE(1),COUNT(3),ALG-ID(1), KEY-ID(2),DATA(C-3)	C+4

The numbers in parentheses are the number of octets in the field.

REFERENCES

[1] Cerf, V., "The Catenet Model for Internetworking," Information Processing Techniques Office, Defense Advanced Research Projects Agency, IEN 48, July 1978.

[2] Postel, J., "DOD Standard Internet Protocol," USC/Information Sciences Institute, IEN 128, NTIS number AD A079730, January 1980.

[3] Postel, J., "DOD Standard Transmission Control Protocol," USC/Information Sciences Institute, IEN 129, NTIS number AD A082609, January 1980.

[4] Postel, J., "Assigned Numbers," RFC 762, USC/Information Sciences Institute, January 1980.

[5] Feinler, E. and J. Postel, eds., "ARPANET Protocol Handbook," NIC 7104, for the Defense Communications Agency by the Network Information Center of SRI International, Menlo Park, California, Revised January 1978.

[6] Neigus, N., "File Transfer Protocol for the ARPA Network," RFC 542, NIC 17759, SRI International, August 1973.

[7] Bhushan, A., K. Progran, R. Tomlinson, and J. White, "Standardizing Network Mail Headers," RFC 561, NIC 18516, September 1973.

[8] Myer, T., and D. Henderson, "Message Transmission Protocol," RFC 680, NIC 32116, 30 April 1975.

[9] Crocker, D., J. Vittal, K. Progran, and D. Henderson, "Standard for the Format of ARPA Network Text Messages," RFC 733, NIC 41952, 21 November 1977.

[10] Barber, D., and J. Laws, "A Basic Mail Scheme for EIN," INWG 192, February 1979.

[11] Braaten, O., "Introduction to a Mail Protocol," Norwegian Computing Center, INWG 180, August 1978.

[12] Crocker, D., E. Szurkowski, and D. Farber, "An Internetwork Memo Distribution Capability - MMDF," Sixth Data Communications Symposium, ACM/IEEE, November 1979.

[13] Haverty, J., D. Henderson, and D. Oestreicher, "Proposed Specification of an Inter-site Message Protocol," 8 July 1975.

[14] Thomas, R., "Providing Mail Services for NSW Users," BBN NSW Working Note 24, Bolt Beranek and Newman, October 1978.

[15] White, J., "A Proposed Mail Protocol," RFC 524, NIC 17140, SRI International, 13 June 1973.

[16] White, J., "Description of a Multi-Host Journal," NIC 23144, SRI International, 30 May 1974.

[17] White, J., "Journal Subscription Service," NIC 23143, SRI International, 28 May 1974.

[18] Levin, R., and M. Schroeder, "Transport of Electronic Messages Through a Network," Teleinformatics 79, Boutmy & Danthine (eds.) North Holland Publishing Co., 1979.

[19] Earnest, L., and J. McCarthy, "DIALNET: A Computer Communications Study," Computer Science Department, Stanford University, August 1978.

[20] Crispin M., "DIALNET: A Telephone Network Data Communications Protocol," DECUS Proceedings, Fall 1979.

[21] Caulkins, D., "The Personal Computer Network (PCNET) Project: A Status Report," Dr. Dobbs Journal of Computer Calisthenics and Orthodontia, v.5, n.6, June 1980.

[22] Postel, J., "NSW Transaction Protocol (NSWTP)," USC/Information Sciences Institute, IEN 38, May 1978.

[23] Haverty, J., "MSDTP -- Message Services Data Transmission Protocol," RFC 713, NIC 34739, April 1976.

[24] Haverty, J., "Thoughts on Interactions in Distributed Services," RFC 722, NIC 36806, 16 September 1976.

[25] Postel, J., "A Structured Format for Transmission of Multi-Media Documents," RFC 767, USC/Information Sciences Institute, August 1980.

[26] ISO-2014, "Writing of calendar dates in all-numeric form," Recommendation 2014, International Organization for Standardization, 1975.

[27] ISO-3307, "Information Interchange -- Representations of time of the day," Recommendation 3307, International Organization for Standardization, 1975.

[28] ISO-4031, "Information Interchange -- Representation of local time differentials," Recommendation 4031, International Organization for Standardization, 1978.

[29] CCITT-X.121, "International Numbering Plan for Public Data Networks," Recommendation X.121, CCITT, Geneva, 1978.

[30] Postel, J., "NSW Data Representation (NSWB8)," USC/Information Sciences Institute, IEN 39, May 1978.

[31] Cohen, D., "On Holy Wars and a Plea for Peace," IEN 137, USC/Information Sciences Institute, 1 April 1980.

[32] Hofstadter, D., "Godel, Escher, Bach: An Eternal Golden Braid," Basic Books, New York, 1979..

[33] Harrenstien, K., "Field Addressing," ARPANET Message, SRI International, October 1977.

[34] Postel, J., "Out-of-Net Host Address for Mail," RFC 754, USC/Information Sciences Institute, April 1979.

[35] Shoch, J., "On Inter-Network Naming, Addressing, and Routing," IEEE Computer Society, COMPCON, Fall 1978.

[36] National Bureau of Standards, "Data Encryption Standard," Federal Information Processing Standards Publication 46, January 1977.

[37] Diffie, W., and M. Hellman, "New Directions in Cryptology," IEEE Transactions on Information Theory, IT-22, 6, November 1976.

[38] Rivest, R., A. Shamir, and L. Adleman, "A Method for Obtaining Digital Signatures and Public-Key Cryptosystems" Communications of the ACM, Vol. 21, Number 2, February 1978.

[39] Merkle, R., and M. Hellman, "Hiding Information and Signatures in Trapdoor Knapsacks," IEEE Transactions of Information Theory, IT-24,5, September 1978.